FORMATION AND EVOLUTION OF IONIAN MOUNTAINS. E. P. Turtle[1], A. S. McEwen[1], L. P. Keszthelyi[1], and P. M. Schenk[2]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721-0092; turtle@lpl.arizona.edu. [2]Lunar and Planetary Institute, Houston, TX 77058.

Introduction: Io is the most volcanically active planet in the solar system and yet its tallest mountains do not appear to be volcanoes. Indeed, although mountains are sometimes associated with volcanic centers, there is no correlation between mountain locations and the numerous hot spots and plumes observed on Io's surface. Carr *et al.* [1] have tabulated ~100 Ionian mountains and plateaus many of which have been determined from shadow measurements or stereo photogrammetry to be several kilometers high (*e.g.*, Figure). The highest mountain measured to date is Boosaule Montes, which is 16 ± 2 km tall [2]. To first order, mountains appear to be evenly distributed over Io, but there may be some variations with longitude [2]. There are no obvious global tectonic patterns, as there on Earth where mountains are associated with volcanism or regional compression, which might give us insight into the forces driving mountain formation. Some of the mountains look like eroded volcanoes. Many others have the appearance of tilted blocks which are bounded by steep scarps and, in many cases, fractured.

Io has a global average resurfacing rate of 1 to 2 cm/yr which implies a comparable global subsidence rate. After one million years, the amount of crustal shortening resulting from this subsidence can be accommodated by ~110 mountains, assuming they are all formed by low-angle thrust faulting as Schenk and Bulmer proposed for Euboea Montes [2]. Of course this is greatly oversimplified, the differences in mountain morphology imply that there may be a few different formation mechanisms at work. Furthermore, the resurfacing is not uniform; regions far from vents may experience 0.1 cm/yr (or less?), while in active regions there may be as much as 150 cm deposited in the same time period.

We are performing finite-element simulations to explore possible formation mechanisms for Ionian mountains. Our investigation focuses on relative motions of individual crustal blocks that may be subsiding, tilting, or overriding other blocks due to local differences in crustal density or resurfacing rates.

Modeling: We are using the two-dimensional version of the finite-element code Tekton which was developed for use in simulating tectonic processes [3]. We have designed a mesh that extends vertically from a depth of 175 km to an elevation of 15 km. The reason for extending the mesh above the surface is to allow addition of material to simulate volcanic resurfacing. The mesh extends out to a distance of 1000 km. It has rectangular elements 10km wide which range from 1 to 10 km high depending on their proximity to the surface where simulating resurfacing demands a finer scale.

Our current models have been based on the theory that Io may have a crystal-rich magma ocean [4]. We use a 50 km thick lithosphere with a density of 2900 kg/m^3 overlying a mantle which is represented by a Newtonian fluid with a viscosity of 10^{10} Pa s and a density of 3000 kg/m^3. This viscosity is above the minimum range of 10^7-10^9 Pa s predicted by Webb and Stevenson from their analysis of topographic subsidence on Io [5]. The low density contrast between the crust and the mantle is predicted from the lack of differentiation that would occur in the magma ocean model [4]. Indeed, in this model it is possible for the crust to be slightly denser than the mantle. An alternative model for Io is that its crust is the result of extreme differentiation [6]. This predicts a crustal density between 2600 and 2900 kg/m^3 and a mantle density in excess of 3300 kg/m^3, resulting in a significantly higher density contrast. We plan to investigate this possibility as well.

We ran a simulation of an unfaulted lithosphere to investigate flexural models. After loading a 200 km wide region with a 15 km thick deposit of lava with a density of 3000 kg/m^3, the downward lithospheric displacement at the center of the load was ~5 km. Therefore, the resulting plateau was ~10 km high. There was a ~1 km high flexural bulge at a distance of ~300 km. This is an oversimplified model; there is a vertical scarp at the edge of the emplaced lavas and there is no infilling of the moat. Nonetheless, it illustrates that flexural support may be an unrealistic explanation for Ionian topography. First, this model would require a correlation of topography with volcanism, which is not observed. Secondly, it would affect topography in a wide region around the mountain, which also does not appear to be the case. Although we do not have high enough topographic resolution to be able to detect flexural moats and bulges directly, in a brief survey of Ionian mountains we found no obvious examples of lava flows near mountains which appeared to have been controlled by topographic expression associated with flexural support.

We have also run simulations in which the lithosphere is cut every 100 km by vertical faults. In these cases the two blocks that are loaded with lava subside under the load and, while the adjacent blocks are relatively unaffected, the blocks beyond them tilt inward with scarps of ~0.5 km facing away from the location of deposition. Unfortunately, these runs become numerically unstable due to extreme deformation of the elements near the subsiding block. However, the occurrence of tilting blocks in the preliminary results is encouraging. These simulations are quite sensitive to the density contrasts between the mantle, the crust, and the extruded lavas which are, unfortunately, not well constrained.

We are continuing to investigate the block tilting mechanism, incorporating faults with non-vertical dips and varying parameters such as the magnitudes of the density contrasts and lithospheric thickness. Our vertically faulted simulation implies that there may be significant coupling between adjacent blocks. We will determine just how closely coupled neighboring blocks are and what parameters influence this. Finally we hope to incorporate the stress and thermal effects of the high rate of subsidence that must accompany Io's rapid global resurfacing rate.

References: [1] Carr, M.H. *et al.*, *Icarus* **135**, p. 146, 1998. [2] Schenk, P.M. and Bulmer, M.H., *Science* **279**, p. 1514, 1998. [3] Melosh, H.J. and Raefsky, A., *Geophys. J. Roy. Astr. Soc.* **60**, p. 333, 1980. [4] Keszthelyi, L. *et al.*, *LPSC* **XXX**, #1224 1999. [5] Webb, E.K. and Stevenson, D.J., *Icarus* **70**, p. 348, 1987. [6] Keszthelyi, L. and McEwen, A.S., *Icarus* **130**, p. 437, 1997.

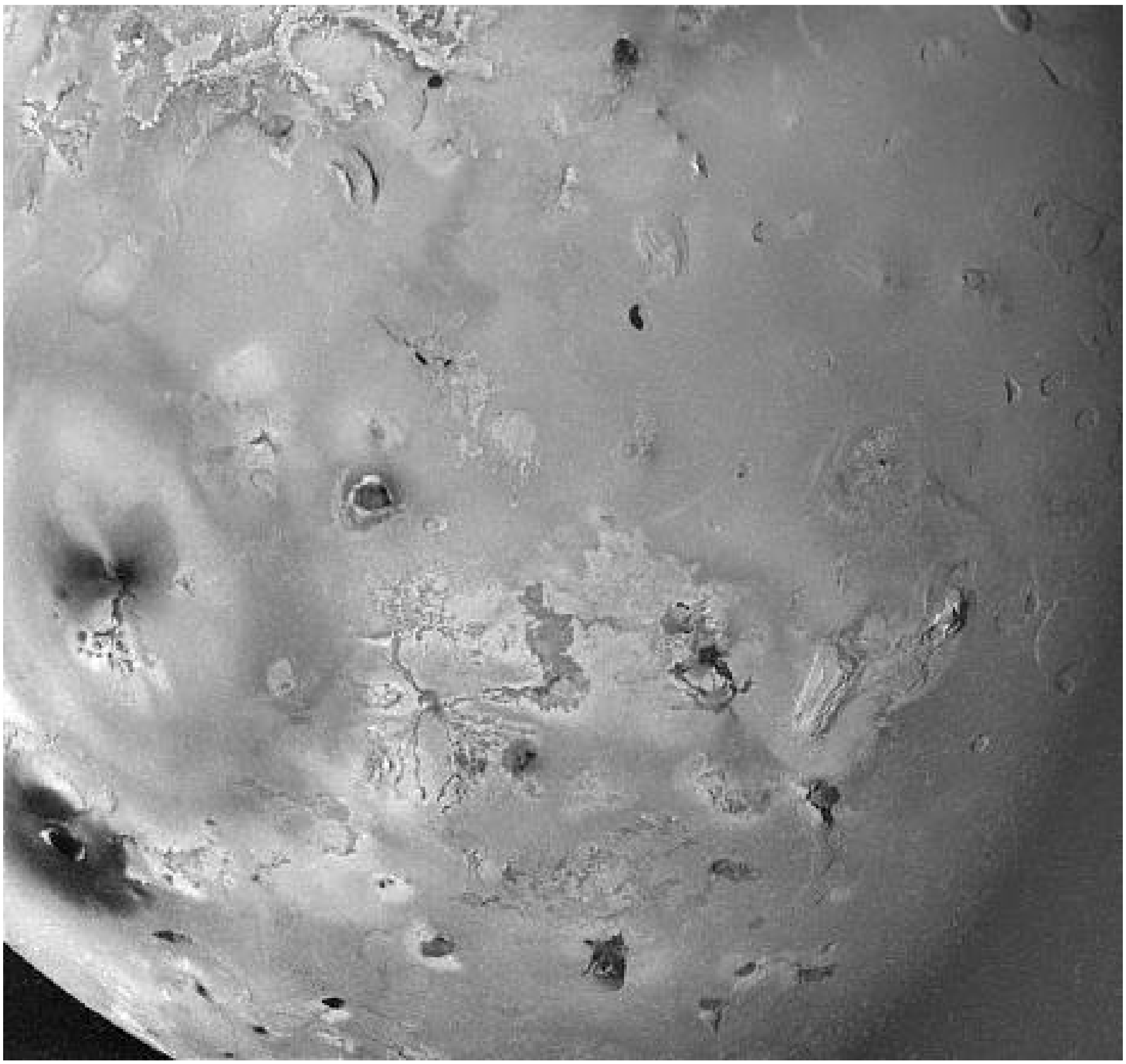

Figure: Galileo image (taken on 6 November 1996, during orbit C3) illustrating examples of Ionian mountains. The image is 2390 km wide and has a resolution of 3.0 km/pixel. The mountains to the lower right (Dorian Montes, above, and Rata Mons, below,) are ~5 km high.